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Estimation of energy saving potential in China's paper industry

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ABSTRACT

The objective of this paper is to estimate the energy saving potential in China's paper industry by determining energy intensity under different scenarios. Cointegration model and stability test are applied to formulate the equilibrium equation. Results show that energy price, industry structure, profit margin and technology have significant impact as they are negatively correlated to changes in energy intensity. Three scenarios (BAU (business as usual), intermediate and active) are designed to estimate the future trend of energy intensity in paper industry. In 2010, the energy intensity (energy consumption per unit of value added) was 4 tce/10,000 RMB, and by the scenarios it is expected to considerably decline. According to the BAU (business as usual) scenario, the energy intensity will decrease to 2.56, 1.43 and 0.70 tce/10,000 RMB by 2015, 2020 and 2025, respectively. With respect to the intermediate scenario it is expected to drop further to 0.44 tce/10,000 RMB. Yet by the active scenario, the energy intensity is expected to considerably decline to 0.36 tce/10,000 RMB by 2025. Using the BAU forecast as a baseline, the quantity of energy savings is estimated to be 185.6 billion tce by 2025. Considering this important potential, we also provided some policy suggestions.

1. Introduction

For the past 30 years, Chinese paper industry experienced sustained and rapid development. The demand for paper and paperboard products in the local and international market can explain this remarkable growth. Since 1990, China's consumption has been growing at the rate of 10% annually. The production of paper in 1985 was estimated to be about 11.2 million tons. It increased to 35 million tons by 2000 and 96.5 million tons in 2010, representing 24% of the total global production [1]. China is presently the largest producer of paper and paperboard products (1.06 billion tons) ahead of the United States with 750.78 million tons of production capacity. The paper industry is crucial and important for China considering the constant growth in demand. However, it is a capital and energy intensive industry. It is also reported to be a polluting industry in the Chinese economy. In 2008, the carbon dioxide emissions from paper and paper products represented 2% of emissions from the Chinese industries [2]. Therefore, analysis of the energy intensity in the paper industry has a double advantage: economic and environmental aspects. It is important to provide methods to cut down the cost of energy, by reducing the quantity of energy required per value added; moreover, it is useful to reduce emissions by using less energy. As the production increased (from 11.2 in 1985 to 96.5 ton million in 2010), issues and challenges regarding energy management become inevitable. In 1985, the energy consumption in the paper industry was estimated to be about 12.95 million tce (million tonne of coal equivalent). Over the years, it grew to 22.69 million tce in 2000 and 39.61 million tce by 2010 [3]; which led to a decrease of energy intensity but in an irregular trend. Reducing the energy intensity will not only decrease the energy demand, but also help cutting down the carbon dioxide emissions. The reduction of CO_2 has become an important target for countries, including China. Thus, application of energy conservative measures in the paper industry is imperative considering the potential dangers of hazards on the environment, society and economy in general. The Chinese paper industry is unique compared to those of the USA or Europe; it is the largest user of non-wood fibers as input for production. In the 1990s, the use of wood fiber as an input represented only 7%, recovered paper represented 36%, and the remaining 57% was imported waste paper and non-wood fiber [3]. Until the mid-2000s, more than 70% of the pulp and paper mills used non-wood fiber as input. Despites that use of non-wood fiber as input in the paper industry will not drastically decline, but will continue to decrease in the near future. During 2000s, to improve the efficiency of the paper industry, the

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Chinese government closed down most of small polluting and inefficient mills, which represented an important proportion of total mills in that industry. Recently, modern and large-scale paper machines have been installed; for instance Hebei Norske Skog Long 300,000 t/year plant, paper machine with a production capacity of 1.1 million tons per year was installed at Dagang. Consequently, non-wood fiber is expected to continue to play an important and vital role in the future of Chinese paper industry. The enhancement of energy efficiency will led to reduce carbon dioxide emissions. Therefore, it is important to analyze the Chinese paper industry on its potential in energy saving which undeniably will contribute to carbon mitigation. In this context, it is important to study questions such as: (i) what factors have influence on energy intensity in China's paper industry? (ii) What are their degrees of influence? (iii) What will be the energy intensity level in the near future? What is the current energy saving in China's paper industry? Answers to these questions will be useful in several aspects; it will provide policy suggestions on energy conservation matter, contribute to the developmental strategy of the paper industry to improve productivity and competitiveness, and fill the large gap in the scientific research on energy efficiency in Chinese industries. Furthermore, it will also give useful insight and orientation for policy interventions on energy savings and industrial development for developing countries.

The remainder of this paper is organized as follows. Section 2 presents a brief literature review. Section 3 gives an overview on energy intensity in China's paper industry. Section 4 outlines the methodology and data sources. Section 5 presents results and interpretation. Section 6 summarizes our findings and policy recommendations.

2. Literature review

A lot of studies have been done on the issue of energy intensity. Generally, those researches have been technically oriented or economically oriented. In this paper, we follow the economic orientation. Several analytical approaches have been applied. Fleiter et al. [4] used a techno-economic approach to assess energy efficiency improvement in the German pulp and paper industry up to 2035. For technology-specific analysis of energy demand, bottom-up models have been widely used. For instance, McKane and Hasanbeigi [5] applied the bottom-up energy efficiency supply curve models to estimate the cost-effective electricity efficiency and potential as well as CO_2 emissions reduction for industrial motor systems in some selected countries. Hasanbeigi et al. [6] also used the bottom-up ECSC (Electricity "Conservation Supply Curve") model to estimate the electricity efficiency potential for 16 cement plants in Guangdong province, China. The model has the advantage that it describes the quantity of energy saved relative to costs of potential saving options. However, the limitation is that it is only focused on current available technology [4].

Cointegration approach has also been used to analyze the relationship between variables affecting energy intensity. Cheng-Lang et al. [7] assessed the causality effect between sectorial electricity consumption in Taiwan using linear and nonlinear causality tests, and established a nonlinear bi-directional causality between total electricity consumption and output level. They also reported unidirectional nonlinear causality from output level to residential electricity consumption. Despite the accuracy of this method in establishing relationship between variables, it is not been widely used for the estimation of efficiency and energy saving potential in the literature. Perhaps due to the fact that application of the cointegration approach requires high quality, stability and long term availability of data [8].

DEA (Data development analysis) approach is another technique that has been used in this regard. Hu and Kao [9] employed this method to estimate input targets (Energy, labor, and capital) leading to improvement of energy-saving in the APEC (Asia-Pacific Economic Cooperation) economies. Zhou and Ang [10] also used the model in the case of Latin American and OECD (Organisation for Economic Co-operation and Development) countries to analyze CO_2 emissions. Using panel data, the production frontier and several production technology related components were estimated. Recently, Blomberg et al. [11] conducted empirical assessment of efficiency improvement potential for electricity usage in the Swedish pulp and paper industry. To achieve this, they combined DEA (data development analysis) and mill-specific input and output data over a range of period.

Index decomposition analysis has also been applied for these kinds of analyses. Ma and Stern [12] applied a LMDI (logarithmic mean divisia index) technique to decompose changes in energy intensity in china during the period 1980–2003 and concluded that technology has a negative impact on energy intensity. More recently, similar methods were applied by Refs. [13–15]. Notwithstanding, these methods have limitations because they do not consider an important factor such as price. Additionally, they are not sufficient enough to exactly assess and forecast saving potential capacity [16,17].

Clearly, several different approaches have been adopted to analyze the energy efficiency and intensity, yet few have been done on energy saving potential in the paper industry. In fact, report on the prediction of energy saving potential in this area is limited. Consequently, we employed cointegration technique not only to capture and establish relationship between variables, but also to formulate and facilitate prediction of future energy intensity trend and energy saving potential. In view of this, we analyzed variables that affect energy intensity in Chinese paper industry, formulated cointegration equation involving the variables, constructed different scenarios, and finally forecasted the energy saving potential for the industry up to 2025.

3. Energy intensity and factors affecting saving potential

In this paper, energy intensity is defined as the ration of energy consumption and industrial valued added of the Chinese paper industry (energy consumption per unit of value added). Several factors influence energy intensity change over time. Respective evolutions of these factors compared with energy intensity trend provide understanding and analyses of their relationship. Factors we considered are: EP (energy price), IS (industry structure), PM (Profit margin) and TD (Technology).

3.1. EP (energy price)

The energy price is one of the most important factors in terms of energy consumption. Negatively correlated to energy intensity, an increase in energy price has the consequence to improve the energy efficiency. Hang and Tu [18], in reviewing the deregulation of energy price in China, reported a negative relationship between energy intensity and price elasticity of energy, and recommended that energy prices must be raised to boost efficiency. Birol and Keppler [19] analyzed the role of energy efficiency to reduce energy consumption while maintaining growth. They found that price is one of the main factors affecting energy consumption; according to them, an increase in energy price through economic instruments leads to enhanced energy efficiency. However, in this study, because of lack of available data, raw material and fuel price indexes is taken as the proxy [20].